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CURRENT RESEARCH FOR SPACE TRAVEL
Nutrition and Food Technology

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6570th AEROSPACE MEDICAL RESEARCH LABORATORIES
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In April of 1959, seven selected members of the Department of Defense volunteered to become the first astronauts for the United States. In this relatively brief period, our accomplishments in space technology have been sufficiently great to permit manned orbital flights. What lies ahead? At this moment a two-man spaceship is being developed. This vehicle will provide the vital link between the first step into outer space and a lunar expedition. Reaching for the moon is no longer the fantastic and impossible. It is a goal. Let me hasten to add, however, that research is necessary before a trip to the moon is realized. The success of this lunar adventure rests upon the technical know-how, imagination, and creativity of many persons. New ideas in diverse areas must be explored, tested, and evaluated. This paper covers some of the current research in nutrition and food technology and some of the research contemplated for the future.

Nutrition Research

1. Nutritional Requirements

To date several feeding systems for the space traveler have been recommended by the 6570th Aerospace Medical Research Laboratories (ref. 13). These have been based on National Research Council recommendations i.e., on dietary allowances designed to maintain good nutrition for healthy persons living in the United States under contemporary conditions. These allowances, at the moment, represent the best available information and were used with full and complete knowledge that they may not be entirely satisfactory for the astronaut while orbiting in a space vehicle. Hence, a research program has been initiated to determine the most suitable distribution of carbohydrate, protein, fat, and other nutrients for the optimum efficiency of man while subjected to prolonged periods of inactivity. Immobilization is used to simulate the astronaut's state of reduced dynamic stress, since weightlessness cannot be duplicated on earth except for very brief periods. This research provides baseline data concerning the type, time of onset, degree, and duration of metabolic and physiological alteration that can be expected when men who are well fed and physically fit are subjected to complete bed rest for prolonged periods. Bed rest does not simulate weightlessness, but it is a practical although indirect method for obtaining the reduced dynamic state. The resulting physiological, and biochemical measurements

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will give some much needed information upon which advanced feeding programs can be formulated (ref. 2).

2. Nutritional Individuality

Dr. Roger J. Williams (ref. 14) provides evidence of the existence among healthy animals and men of marked differences in body composition, blood components, enzyme levels, hormone activities, and urinary excretion patterns. These variations point to the probable existence of wide differences in nutritional requirements among men. When considering the logistics of space travel, particularly for long-duration missions during which food stores cannot be replenished, the need for further knowledge concerning nutritional individuality is obvious; for example, large requirements by an astronaut for a specific nutrient (or nutrients) when on a limited food supply not capable of meeting this demand may interfere with his efficiency and effectiveness in flight.

Based on this consideration, research was begun on the development of a suitable and economic procedure for ascertaining protein and specific amino acid needs of man when either adequately fed or nutritionally comprised. Measurements of human plasma amino nitrogen and plasma essential amino acids provide adequate and reliable criteria for the quality and quantity of dietary protein in normal, healthy adults, (ref. 1). Further research to confirm the reliability of the plasma amino nitrogen method is currently in progress. Experiments reveal that, in general, lysine, threonine, phenylalanine, isoleucine, and leucine follow the plasma amino nitrogen changes whereas methionine and valine act independently. Preliminary data correlate well with classical nitrogen balance data for both negative and positive states (ref. 1). Thus, another link may be added to the chain permitting formulation of an adequate feeding system for the astronaut.

3. Nutrition and Altered Atmosphere

By nature, man is an earthbound creature. From the atmosphere on earth he receives the supply of oxygen and sufficient air pressure he needs to function satisfactorily. But as he goes higher above the earth there is less oxygen and pressure. To survive, he must carry an earthlike environment with him. The 6570th Aerospace Medical Research Laboratories has completed one phase of a project oriented to determine: (1) the type and concentration of the gas or gases man needs to function well, both physically and mentally, while on an extended space flight, (2) the pressures these gases should exert, and (3) which acceptable combinations of gases and gas pressures are compatible with a space vehicle. For this effort an environmental test cell was used which permitted the exposure of human subjects to artificial atmospheric compositions for varying periods. This program included many areas of biomedical investigations. The facet of most interest to us pertained

to the effects of this environment on nutritional requirements. Two isocaloric diets with equivalent distribution of carbohydrate, protein, fat, sodium, and potassium were fed on alternate days to volunteer subjects. Data from this metabolic study were gathered to determine the effects of pure oxygen on the metabolism of man. Some of the biomedical information will be presented at the April 1963 meeting of the Federation of American Societies for Experimental Biology.

4. Nutrients and Radiation Protection

Radiation protection for the space traveler is a matter of grave concern. A research program was conducted to determine how dietary changes might afford protection to animals from the effects of low-level doses of gamma radiation received over an extended period. Resulting data indicated that, in the rat, the effects of radiation were neither diminished nor accentuated by alterations in the protein and amino acid content of the diet. This was true for cystine-supplemented casein as well for mixtures of amino acids that were isonitrogenous (ref. 5). The effect of increased amounts of B-vitamins in the diet was studied. Again, data indicated little or no protective response with respect to growth rate, survival, organ weight, and histology (ref. 4). A study recently completed investigated the potential of dietary antioxidants in protecting man against low-level ionizing radiation. Ascorbic acid significantly prolonged the survival time of rats (ref. 3).

<u>Food Technology</u>

1. Precooked-Dehydrated Foods

The objective of the nutrition research program, therefore, is to determine what the astronaut requires to cope adequately with his environment and the limitations of the space vehicle. In like manner, restrictions imposed by the spacecraft and its environment make certain demands on the type and variety of food that may be made available to the astronaut.

The need for concentrated and precooked-dehydrated food packaged in lightweight, flexible containers has been previously documented (ref. 4). This type of food will be readily reconstituted in flight with purified, reclaimed water, either hot or cold. Foods will be specially packaged to permit consumption under conditions of weightlessness. Research and development toward this end has progressed well. As a result of intensive efforts by the Armed Forces Food and Container Institute and by industry, a wide variety of precooked freeze-dehydrated foods are now available to satisfy the requirements of early space travel. As with any food item after initial development, efforts will continue toward product improvement and increased storage stability.

2. Food Monotony

For some time now the Armed Forces have been aware that any food or type of food regularly fed for long periods diminishes in acceptability and, therefore, is eaten in reduced quantities. This effect has been noted time and again with food packets both in the laboratory and in operational situations (ref. 9). Since the exclusive use of precooked-dehydrated foods for space flights of 6 months or possibly longer is being considered, a food monotony study was initiated by the 6570 AMRL. This research provided information on changes in food acceptability as well as data on the physiological and psychological effects produced when precooked-dehydrated foods are fed exclusively for 30 days. Healthy male university students served as subjects. They were confined in groups of 3 to a restricted living environment, one which approximated the confinement and isolation of a space vehicle. They were motivated by a knowledge of their contribution to the Air Force space research effort and by an ascending scale of pay for each week they remained with the experiment. Each subject performed in accordance with a prescribed schedule so that he was occupied for appropriate portions of the day. This schedule included psychological and psychomotor testing, time for personal hygiene, cooking, eating, leisure, and sleep. An emergency alarm that simulated a work-under-pressure situation and also required the cooperative effort of the group was included. Physiological measurements and food consumption records were maintained for each subject. Preference ratings of foods were scored daily on a 9-point hedonic scale. Continuous tape recordings of conversations were taken during the time subjects were preparing their food and eating. Samples of conversations for a 15-minute period following meals were also taken. Data from 12 subjects were compared with results obtained from an equal number of control subjects similarly treated and tested. Control subjects received fresh, frozen, and heat-processed foods; otherwise, their diet was the same. The results indicated that a diet composed exclusively of a variety of precooked-dehydrated foods is practical for the space traveler. A diet of this type is considered sufficiently acceptable to maintain the desired efficiency of the astronaut in his confined and isolated environment (ref. 10).

3. Food Encapsulation

A series of semisolid foods and liquids packaged in flexible tubes was developed for fighter aircraft pilots required to wear a pressure suit with a full face helmet (ref. 12). A valved aperture in the facepiece of the helmet permits food to be passed into the mouth. This type of semisolid food was evaluated by Lt Colonel John H. Glenn during his orbital flight.

In the laboratory evaluation of tubed foods, it soon became apparent that bite-size solids should be used along with these foods so that there would be a variety in the consistency of the diet. Consequently, a research program was begun on the encapsulation of bite-size solids. Materials used for coatings were required to be edible and not to exceed a food-to-

encapsulation-material ratio of 4:1. Coatings are required to perform a threefold function: (a) first, to keep the food confined so that it will not crumble in the weightless environment of the spaceship, (b) second, to maintain content of the food, and (c) third, to prevent microbial and chemical spoilage when food is stored unrefrigerated at 70° to 80° F with a relative humidity of 50% for 6 months. These, to be sure, are rigorous requirements.

Research efforts during a 12-month period provided no coating material that could meet Food and Drug Administration approval and could act both as a moisture barrier and a film former. Foods of low moisture content were successfully encapsulated in two steps, using a soft shell capsule with an overwrap. Fudge, pound cake, and brownies were placed in preformed containers of hydroxypropylmethyl cellulose; caramels and pecans were sprayed with a zein solution that formed the capsule shell. Portions of food were then heat-sealed into cellophane-polyethylene laminate bags. Manufacturing quantities of these encapsulated foods, with assurance of maintaining freshness and sterility, requires extensive development of better encapsulating techniques and equipment.

Foods of moderate moisture content, as exemplified by meat, and foods of high moisture content, such as fruits and vegetables, were encapsulated in containers of laminated hydroxypropylmethyl cellulose-gelatin films lined with beeswax. Organoleptically, these food rated low (ref. 11). More intensive research on the encapsulation of foods of high moisture content is needed.

4. High-Energy Metabolites

Those of us involved in the biomedical aspects of space flights are constantly reminded by the engineer of the high cost per pound of payload for space vehicles. To minimize the weight and volume of food for space travel, a basic research program on high-energy metabolites is in progress. The *in vivo* efficiency and utilization of materials with a caloric content higher than carbohydrate, i.e., approximately 6.3 Calories per gram are being investigated in rats. An odd-chain fatty acid, namely 2,4-dimethylheptanoic acid, and a petroleum derivative, 2,3-butanediol, are oxidized in the body of the albino rat without producing ketosis. Rats were studied for a 25-week period during which time all carbohydrate in the diet was replaced with these substances. Animals survived, without adverse effects (ref.8). Additional work is contemplated which will determine the metabolism of high-energy metabolites. A search is also being made for additional compounds (ref. 7). Successful use of such materials by man could lighten the weight of food supplies and thus extend the length of flight.

Future Requirements

For long-duration space flights, much research and development is still necessary to produce a closed and balanced ecological system. This closed system must provide a habitable atmosphere and at the same time produce food for the astronaut. The role of algae, bacteria, fungi, higher plants, and plant tissue grown by tissue culture must still be established. Once this is accomplished, we must determine the availability, utilization, and metabolism of the nutrients present.

Much information is desired concerning man's nutritional requirements while he is engaged in aerospace travel and extraterrestrial habitation. The effects of stress produced by isolation, confinement, vibration, noise, radiation, lack of exercise, and weightlessness--individually and in combination as they relate to metabolism and nutritional physiology--need to be explored. In food technology, suitable, lightweight, flexible packaging for precooked-dehydrated foods must be designed. These containers must store food, permit adding water for reconstitution, and serve as a food dispenser. Data on the chemical basis of food flavor is desired and further insight into the influence of flavor upon food acceptability is needed. If high-energy metabolites, algae, microorganisms, and special plants are to contribute toward meeting the nutritional needs of the astronaut, ways and means must be devised to use these substances as food additives or supplements.

Much research on foods and nutrition for the space traveler remains to be done, and the challenges are many.

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